CLAIMS

What is claimed is:

1. A micro-electro-mechanical system (MEMS) mirror device, comprising:

a mirror having a first surface and a second surface, wherein the first surface comprises a plurality of trenches;

a beam connected to the mirror;

a plurality of rotational comb teeth connected to the beam; and

a first spring connecting the beam to a first bonding pad.

2. The device of claim 1, wherein the second surface comprises a reflective surface.

3. The device of claim 1, wherein the mirror comprises an I-beam like cross-section with a top flange and a bottom flange joined by a web, the top flange forming the first surface and the bottom flange forming the second surface.

4. The device of claim 1, wherein the rotational comb teeth each comprises a tapered shape.

5. The device of claim 1, further comprising a second spring connecting the beam to the first bonding pad.

6. The device of claim 1, further comprising a second spring connecting the beam to a second bonding pad.

7. The device of claim 6, wherein the second bonding pad is defined within the beam.

8. The device of claim 6, further comprising a third spring connecting the beam to the second bonding pad.

9. The device of claim 1, further comprising a first plurality of stationary comb teeth, wherein the first plurality of stationary comb teeth and the plurality of rotational comb teeth are interdigitated in-plane.

10. The device of claim 9, wherein the first plurality of rotational comb teeth is coupled to a first steady or oscillating voltage and the first plurality of stationary comb teeth is coupled to a second steady or oscillating voltage.

11. The device of claim 10, further comprising a second plurality of stationary comb teeth, wherein the second plurality of stationary comb teeth and the plurality of rotational comb teeth are interdigitated out-of-plane.

12. The device of claim 11, wherein the second plurality of stationary comb teeth is coupled to a third steady or oscillating voltage.

13. The device of claim 11, wherein the plurality of rotational comb teeth and the second plurality of stationary rotational comb teeth are coupled to sense a capacitance that indicates a rotational angle of the mirror.

14. The device of claim 1, wherein the beam further comprises a plurality of holes.

15. The device of claim 1, further comprising mirror alignment marks for aligning another device to the mirror.

16. The device of claim 1, wherein a gap surrounding the mirror has a width greater than gaps around other components on the same layer as the mirror.

17. The device of claim 1, wherein the trenches are located along an outer perimeter of the mirror.

18. The device of claim 1, wherein the trenches comprises etched trenches and laser trimmed trenches.

19. A micro-electro-mechanical system (MEMS) mirror device, comprising:

a bottom layer, comprising:

a mirror opening;

a first anchoring pad;

a top layer, comprising:

a mirror located above the mirror opening, the mirror having a top surface comprising a plurality of trenches and a bottom surface comprising a reflective surface;

a beam connected to the mirror;

a first spring connecting the beam to a first bonding pad, the first bonding pad being bonded atop but electrically insulated from the first anchoring pad;

a plurality of rotational comb teeth connected to the beam;

a first plurality of stationary comb teeth connected to a second bonding pad, the second bonding pad being bonded atop but electrically insulated from the first anchoring pad;

wherein the first plurality of stationary comb teeth and the plurality of rotational comb teeth are interdigitated in-plane.

20. The device of claim 19, wherein the mirror has the trenches along an outer perimeter.

21. The device of claim 20, wherein the trenches comprises etched trenches and laser trimmed trenches.

22. The device of claim 19, wherein:

the bottom layer further comprises a second anchoring pad;

the top layer further comprises a second spring connecting the beam to a third bonding pad, the third bonding pad being bonded atop but electrically insulated from the second anchoring pad.

23. The device of claim 22, wherein:

the top layer further comprises a third spring connecting the beam to the third

bonding pad.

24. The device of claim 23, wherein the third bonding pad is located within the beam.

25. The device of claim 19, wherein the plurality of rotational comb teeth and the first plurality of stationary comb teeth each comprises a tapered shape.

26. The device of claim 19, wherein the plurality of rotational comb teeth is coupled to a first steady or oscillating voltage and the first plurality of stationary comb teeth is coupled to a second steady or oscillating voltage.

27. The device of claim 19, wherein the bottom layer further comprises a second plurality of stationary comb teeth, wherein the second plurality of stationary comb teeth and the plurality of rotational comb teeth are interdigitated out-of-plane.

28. The device of claim 27, wherein the second plurality of stationary comb teeth is coupled to a third steady or oscillating voltage.

29. The device of claim 27, wherein plurality of rational comb teeth and the second plurality of rotational comb teeth are coupled to sense a capacitance that indicates a rotational angle of the mirror.

30. The device of claim 27, wherein a first gap around the second plurality of stationary comb teeth has a greater width and depth than a second gap between adjacent teeth in the second plurality of stationary comb teeth, the first gap accommodating a rotation of the rotational comb teeth.

31. The device of claim 19, wherein the beam further comprises a plurality of holes.

32. The device of claim 19, wherein the bottom layer further comprises mirror alignment marks for aligning another device to the mirror.

33. The device of claim 19, wherein:

the bottom layer further comprises a first separation trench;

the top layer further comprises a second separation trench proximate to the first separation trench, wherein the device is singulated along the first and the second separation trenches.

34. A method for making a MEMS mirror device, comprising:

etching a first wafer to form an anchoring pad;

bonding a second wafer having a bottom oxide layer atop the first wafer;

etching the second wafer to form:

a mirror comprising a top surface with trenches;

a beam connected to the mirror;

a spring connecting the beam to a first bonding pad, the first bonding pad being bonded atop the anchoring pad;

a plurality of rotational comb teeth connected to the beam;

a first plurality of stationary comb teeth connected to a second bonding pad, the second bonding pad being bonded atop the anchoring pad.

35. The method of claim 34, wherein said etching the second wafer comprises concurrently etching the trenches and gaps around other components in the second wafer, the trenches having a smaller width than the gaps around the other components in the second wafer.

36. The method of claim 34, wherein said etching the second wafer comprises:

concurrently etching the trenches and gaps around other components in the second wafer;

placing a shadow mask over the top mirror layer; and

etching through gaps around other components in the second wafer.

37. The method of claim 34, wherein said etching the second wafer comprises etching through a gap around the mirror before etching through gaps around other components in the second wafer.

38. The method of claim 34, wherein said etching a first wafer further forms a second plurality of stationary comb teeth.

39. The method of claim 38, wherein said etching a first wafer comprises etching a first gap around the second plurality of stationary comb teeth deeper than a second gap between adjacent teeth in the second plurality of stationary comb teeth.

40. The method of claim 34, further comprising wet etching the bottom oxide layer to release bonded components between the first and the second layers.

41. The method of claim 34, further comprising laser trimming the mirror.

42. The method of claim 34, further comprising forming a reflective layer on a bottom surface of the mirror.